

WIND LOAD ANALYSIS OF SOLAR FARM USING COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT

There are many aspects of the current day technology where the structures are subjected to many kinds of loads. Some of them are wind loads, and some of them are static loads, static loads occur when the physical load like weight or force applied in many cases like beams and structures. But the wind loads occur as the object is resting at the location and the wind is flowing around it. In this paper, such kind of condition taken for the solar panel and the solar farm where the single panel array subjected to higher and lower velocities of wind speeds. In this project, a solar panel array mounted at the ground plane is subject to wind speeds for 5 m/s and 25 m/s to investigate pressure effect on each panel in the array where the panel is placed at 180 to ground plane and 720 to the latitude. The design and simulation of this problem are done using commercial CFD package fluent, a subsidiary of Ansys Inc. The work presented in the paper is done using simulation concepts of computational fluid dynamics. This work helps in getting the overview and optimization of the necessary parts and areas that are affecting by the wind, which can predict the dislocations of the solar panels.

KEYWORDS: Wind Loads, Higher Velocities, Solar Panel, Pressure Effect & Dislocation

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1. INTRODUCTION

In the essence of comfort need, development of the human beings and development of the planet to achieve farther goals, to reach farther distances and to evolve as a higher species. According to many philosophers, harnessing the Sun's power to the maximum extent will make the world look at renewable energy resources. First in the line of producing clean, sustainable energy is solar power.

Around the world, there are so many countries which use solar power to power their homes factories and business locations because of the reliability. With the increase in need of establishing the large-scale solar power generation plants, it is a challenge to overcome the natural calamities such as cyclones and so on. It is essential to predict and conclude what will happen in some scenarios, knowing what's going to happen might help us eradicate any kinds of significant losses that will arise. There are many possible cases where a solar panel structure might be established, therefore it is not possible to simulate every scenario in a single project. In this paper, a solar panel array is wholly immersed in an aerodynamic field at which the pressures and the flow distribution around the area might also affect the neighboring areas and buildings. Studying flow fields is essential. Solar panels mounted on the ground and array configurations are shown in **figure 1a** and **figure 1b**. The basic geometrical terminology of the

solar panel structure is explained in **figure 2** where d is the distance between the top end and lower end of the solar panel where h is the height from the ground plane, and $d/4$ is the size of the single Photo voltaic Panel. From the theoretical aspects of the wind flow and flow distribution of the force standing panel, where the patterns and the flow scheme is explained in the figure 3.



Figure 1: Solar Panels Placed at Ground Level: a – in a Solar Array Configuration, b – in Consecutive Rows.

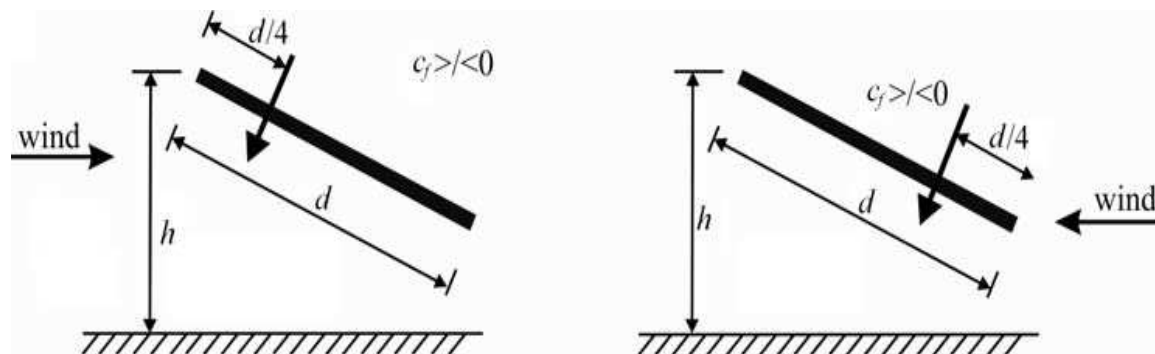


Figure 2: Location of the Application Point of the Global Wind Force Acting on Monopitch Canopies (SR EN 1991-1-4/2006).

2. LITERATURE REVIEW

Georgeta Băetu, Carmen-Elena Teleman, Elena Axinte And Victoria-Elena Roșca [1] has investigated, and study of wind loads of a 300 arrayed panel for the angle of attacks is taken place on 2013 which they explained about the wind load acting with the pressure coefficient. Mehrdad Shademan and Horia Hangan., 2010. The study and CFD simulation to estimate (2010) wind loads are carried out [2]. Ayodeji Abiola-Ogedengbe, Horia Hangan, Kamran Siddiqui [3] found out the critical case scenario in different azimuthal angles between 0 to 180 using RANS turbulence model. The pressure field of standalone PU panels and the pressure distribution of the upper and lower surfaces of the 24 in line. The solar panel is studied experimentally using wind tunnel tests for different directions in 2015. The direction of wind flow and resulting movement due to flow separation is shown in **figure 3(a-c)**. Azimuthal and inclination angles, geometry and dimensions of the domain are shown in **figure 4, 5, 6** respectively. 64 taps are provided on the surface of the solar panel. These are shown as circles. The schematic is shown in **figure 7**. Schematic of wind tunnel is shown in **figure 8**.

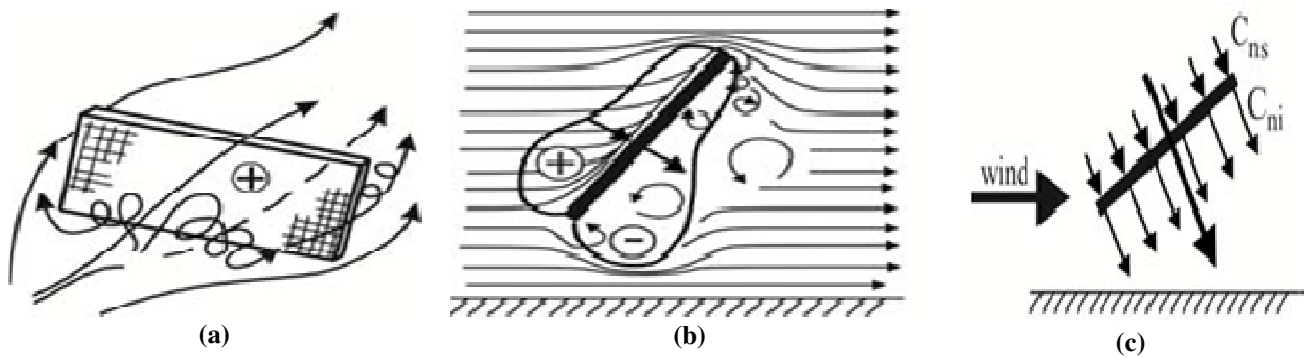


Figure 3: Scheme of a Free-Standing Panel in the Air Flow (a, c –Radu *et al.*, 1986); b – and the Resulting Movement Due to Flow Separation (Bitsuamlak *et al.* 2010).

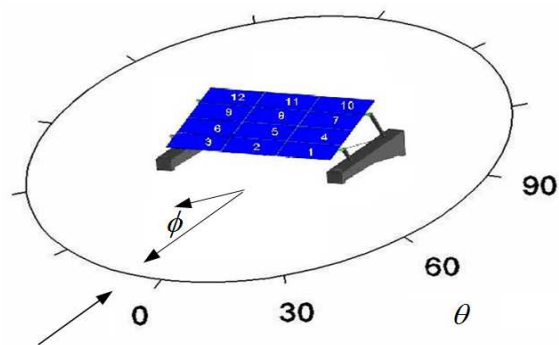


Figure 4: Azimuthal and Inclination Angles.

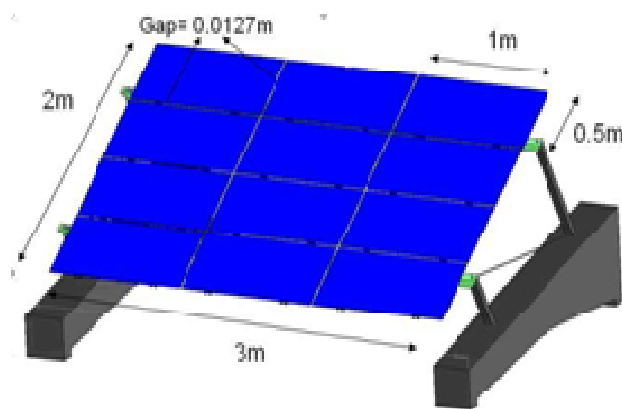


Figure 5: Geometry of a Set of Solar Panels.

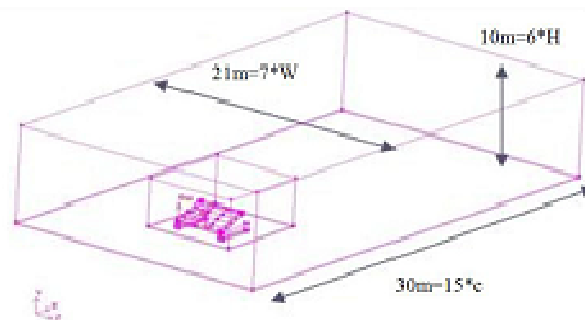


Figure 6: Domain Dimension.

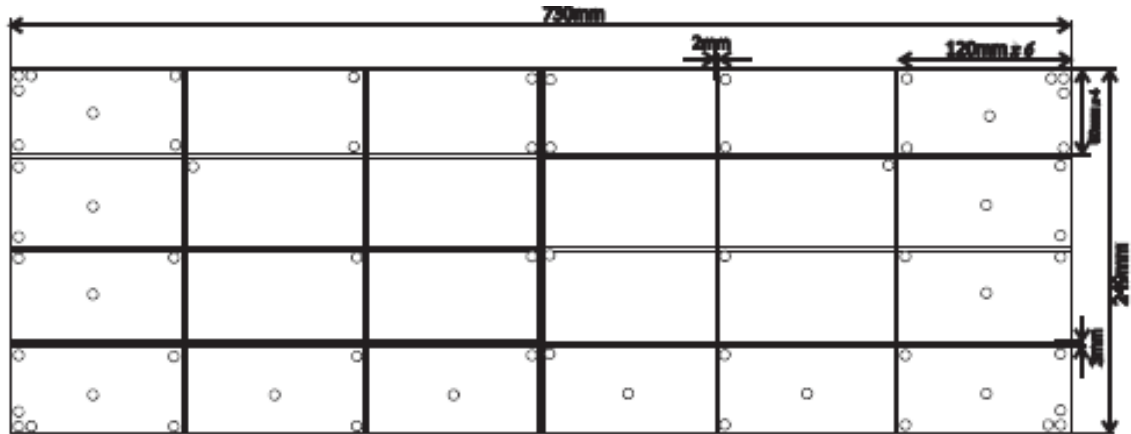


Figure 7: Pressure Taps Layout on the Model PV Structure. There are 64 Taps on each Surface of the Model Shown by the Open Circles.

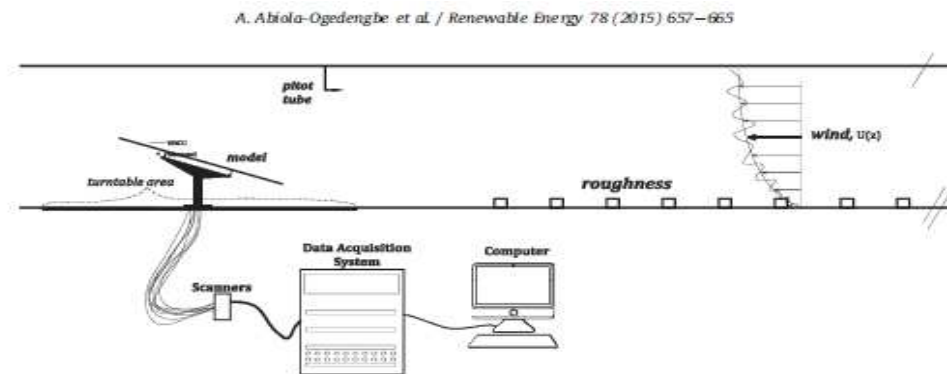


Figure 8: Schematic of the Experimental in the Wind Tunnel.

Aly Mousaad Aly, Girma Bitsuamlak [4] the study of ground-mounted solar panels and test model scale effects are studied using B. L. T. W, i.e., Boundary layer wind tunnel by using the experimental investigation to find out the sensitivity of CFD at geometrical scales in 2013. Different scales which are used are as shown in **figure 9**.

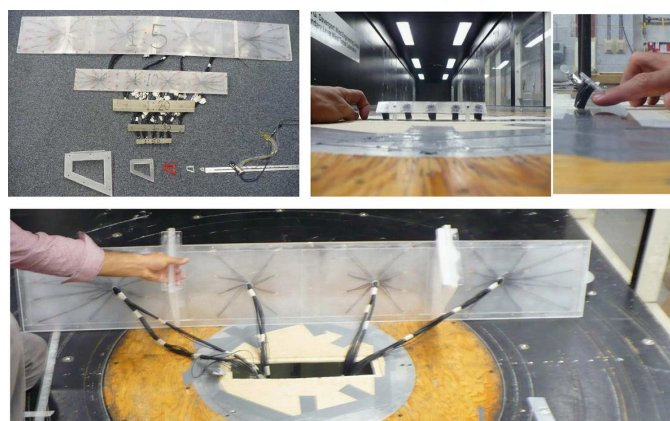


Figure 9: Five Different Scales including 1:50, 1:30, 1:20, 1:10 and 1:5 were Used.

Girma T Bitsumalak, Agerneh K. Dagnew, James Erwin [6]. The study of the ground-mounted solar panel using RANS and LS to determine the pressure distribution and magnitude was investigated experimentally at FIU in 2010. Ground mounted solar panel set up is shown in **figure 10**.



Figure 10: Full-Scale Ground Mounted Solar Panel Setup.

Chowdhury Mohammad Jubayer n, Horia Hangan [7]. The study of ground-mounted solar panels is carried out on the PU systems using 3D RANS simulations using an unsteady solver with the panel inclination of 25 using (K-W) SST turbulence model to find out the mean pressure values and coefficient of drags in 2014. Configuration of PV systems is shown in **figure 11**. Gregory A. Kopp, M. ASCE and David Banks, M. ASCE[8] have conducted the study of the rooftop mounted solar panels to determine wind loads acting on the PU panels by using ASCE 7-0.5 wind tunnel test to determine the loads and if there are any additional requirements. M. Shademan, R. M. Barron, R. Balachandar, and H. Hangan [10] the study and Investigation of flow past ground-mounted the solar panel at different flow directions is carried out for 2*2 sub-panels to determine lateral gap management and optimized spacing to reduce destructive effects. Ted Stathopoulos, Ioannis Zisis, Eleni Xypnitou[11] the study of pressure and other coefficients of solar panels is carried out experimentally using the model equipped measuring devices like pressure in 2013.

3. METHODOLOGY

The numerically simulated process is a step by step process of setting up a known problem where the total project is divided into two phases wherein phase 1, the 12 PV panels are placed in a single mounting array at the geometrical dimensions of the **figure 12** is designed and simulated in the computational Fluid dynamics to see how the Pressure and flow pattern is occurring in 5 and 25 m/s velocities. Panel is mounted to ground at an angle of 18 degrees.

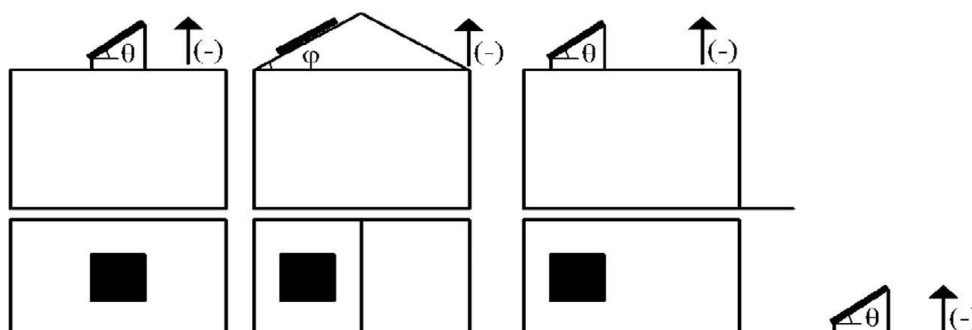


Figure 11: Configurations of Photo Voltaic Systems considered for Comparison to Current Study.

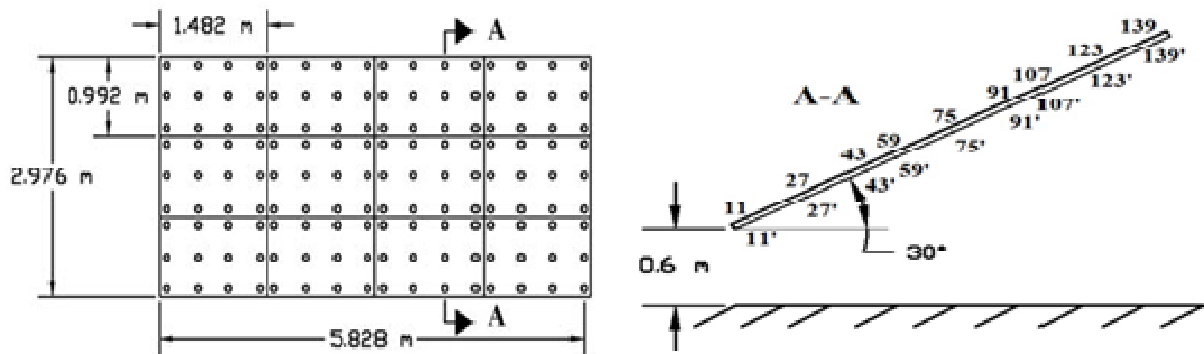


Figure 12: Pressure Points Distribution on the Surface of the Solar Array.

In Phase 2, the same 12-panel array extended to a solar farm with the total of 24 panel mounting structure. A mounting structure is a combination complete Solar pane array with 12 photovoltaic panels. The computational fluid dynamic analysis of phase 1 and 2 are completed using fluent software, a commercial computational fluid dynamics package. The analysis of phase 1 completed for the different angle of attacks 0,30,45,135,1800 and phase 2. The simulation is done for 0 degree to determine the mean pressure values of the solar panel structures (mounts). The total procedure is divided into two parts, i.e., pre-processing and post-processing; Pre processing consists of Geometry, meshing and setup. The geometry of the solar panel and the computational domain is created to simulate using the above-discussed boundary conditions and is shown in **figure 13**. The step by step process of dividing the total established volume into the number of finite set of control volumes. The discretized model of the single panel is shown in **figure 14**. Skewness of the model and orthogonal quality are shown in **figure 15** and **figure 16** respectively.

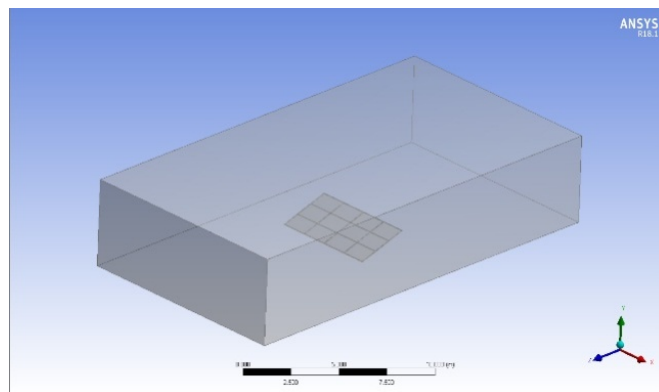


Figure 13: 3d CAD Model.

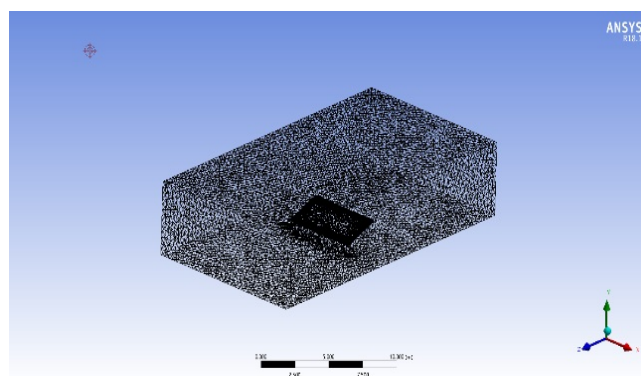


Figure 14: Discretised Model of the Single Panel.

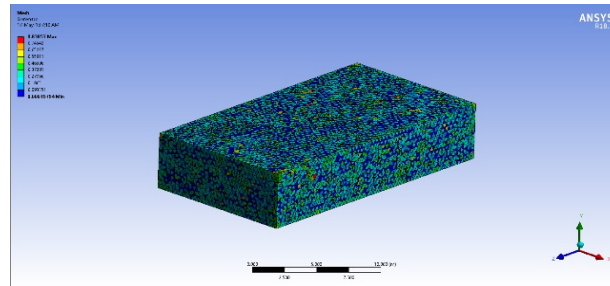


Figure 15: Skewness of the Discretised Domain.

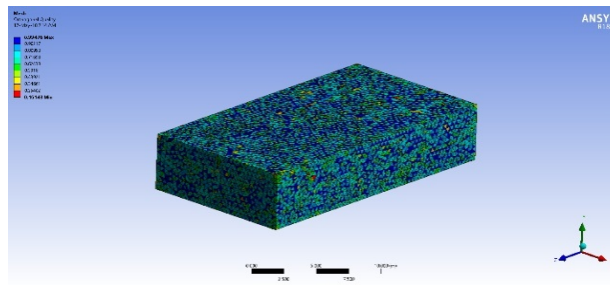


Figure 16: Orthogonal quality of the Domain.

In general, the set up reflects the structure of the problem where the probable settings result in output coming. Therefore, it is essential to appropriate the setting, i.e., taken to solve the problem. In this problem, K-Epsilon turbulence mode taken and the material are chosen air. Where the velocity inlet $U=5\text{ m/s}$ Case 1 25 m/s Case 2 The named selection for PV panels in phase 1 and the solar mounts in Phase 2 is appropriately taken to determine the mean pressure values to determine the angle of attack on the air to solar panel direction is determined from the expression as shown in **Equations 1 and 2**.

$$U_x = U \cos \Theta \quad (1)$$

$$U_y = U \sin \Theta \quad (2)$$

4. RESULTS AND DISCUSSIONS

Pressure Distribution of the solar panel at zero degrees and vector representation of the angle of attack at zero degrees are shown in **figure 17 and 18** respectively. Values of Mean pressure on solar panels at zero degrees of angle are as shown in **figure 19**.

Case 1: $V=5\text{ m/s}$ and $AOA=0\text{ degrees}$.

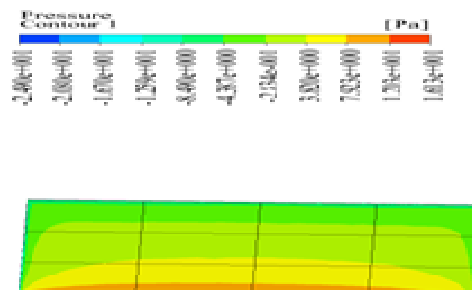
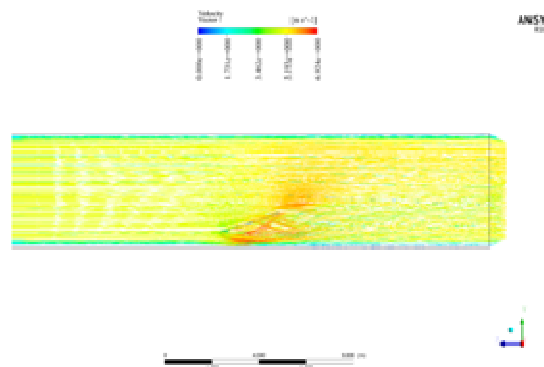


Figure 17: Pressure Distribution of Solar Panel at AOA = 0 Degrees.



**Figure 18: Vector Representation of Angle of Attack
A= 0 Degree.**

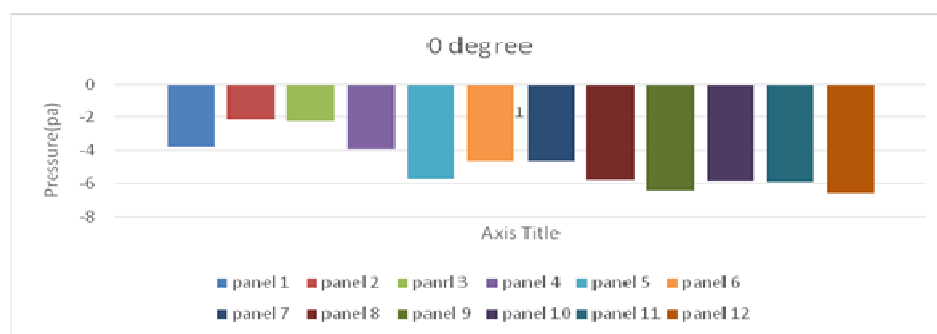


Figure 19: Mean Pressure Values on Solar Panels at AOA = 0 Degree.

Wind Flow Simulation for 24 Array Solar Mounts at 0 degree Angle of attack and 5m/s velocity are shown in figure 20 to figure 33.

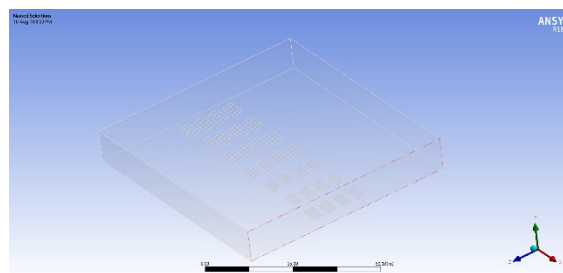


Figure 20: Geometry of Solar Panel Array.

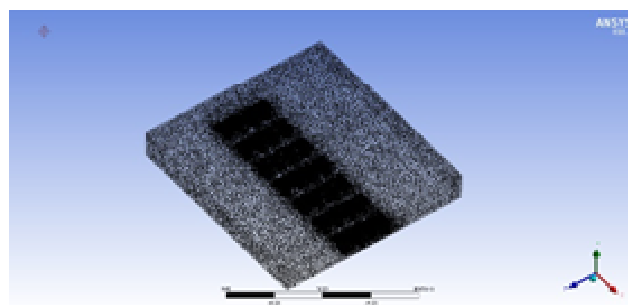


Figure 21: Meshing of the Solar Panel Array.

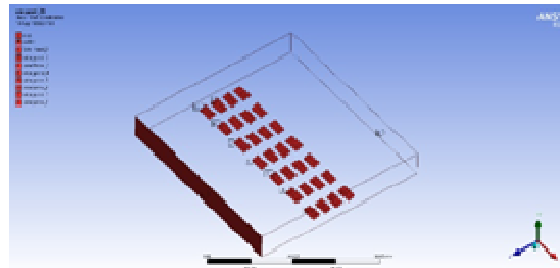


Figure 22: Boundary Conditions.

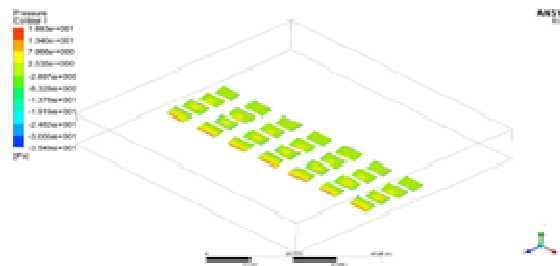


Figure 23: Pressure acting on the Panels due to Fluid Flow $U = 5 \text{ m/s}$.

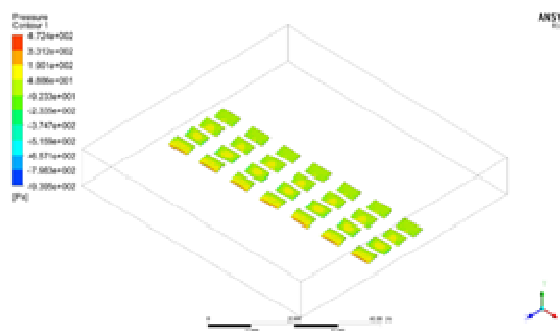


Figure 24: Pressure acting on the Panels due to Fluid Flow $U = 25 \text{ m/s}$.

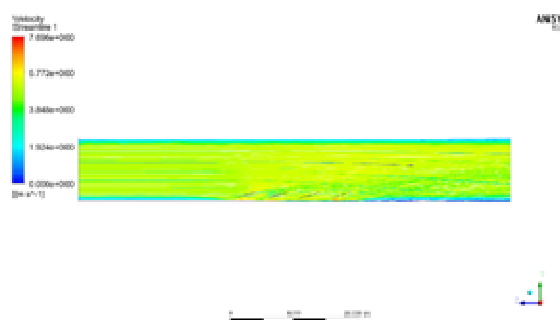


Figure 25: Stream line Flow Over the Panels $U = 5 \text{ m/s}$.

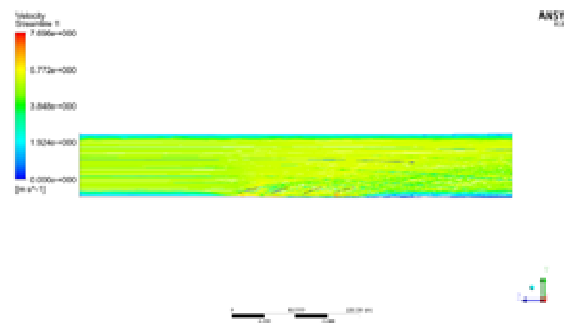


Figure 26: Stream line Flow Over the panels $U=25\text{m/s}$.

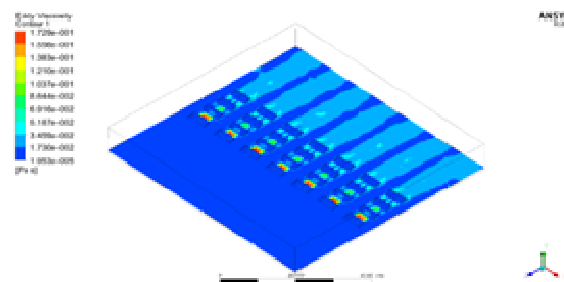


Figure 27: Eddy Viscosity of the Flow in Solar Farm.

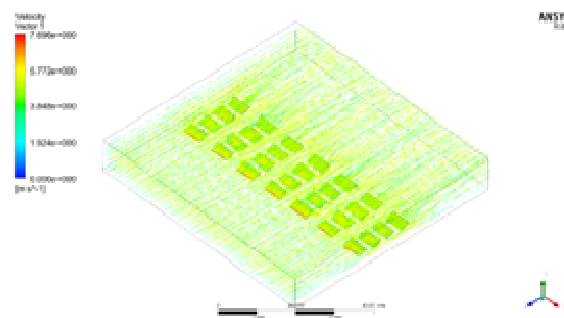


Figure 28: Vector Representation of the Flow in the Solar Farm $U=5\text{m/s}$.

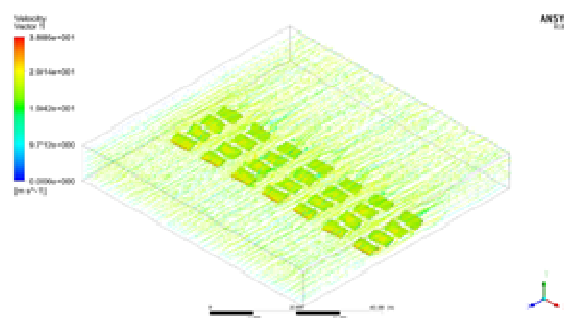


Figure 29: Vector Representation of the Flow in the Solar Farm $U=25\text{m/s}$.

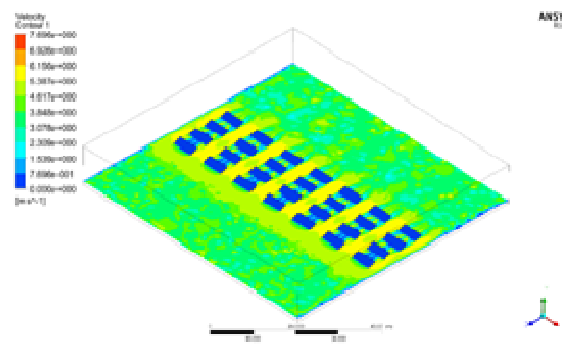


Figure 30: Velocity Distribution of the Wind in Farm. $U=25\text{m/s}$.

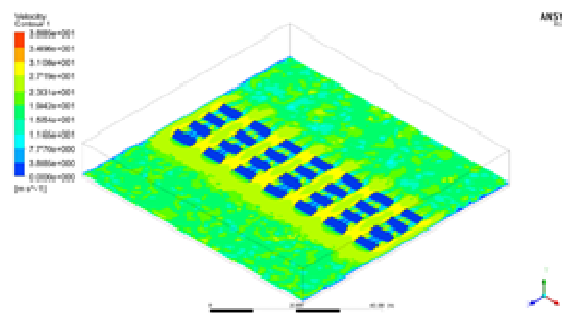


Figure 31: Velocity Distribution of the Wind in Solar Solar Farm. $U=5\text{m/s}$.

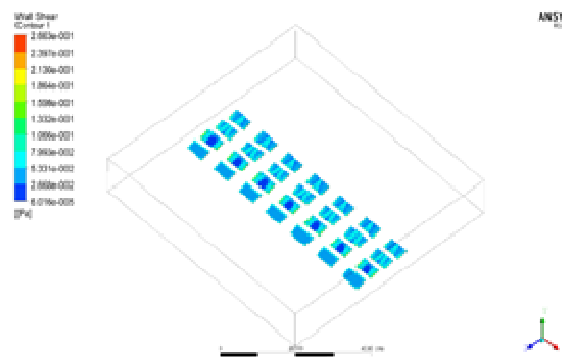


Figure 32: Shear Caused Due to the Flow over the Panel $U=5\text{m/s}$.

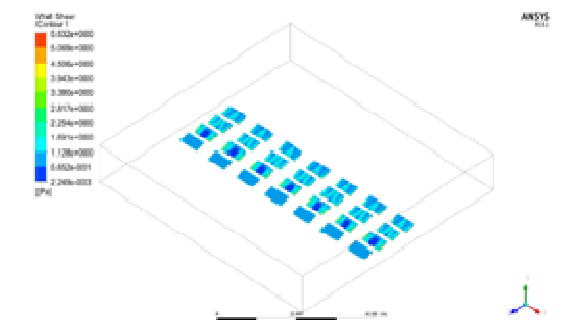


Figure 33: Shear Caused Due to the Flow Over the Panel $U=25\text{m/s}$.

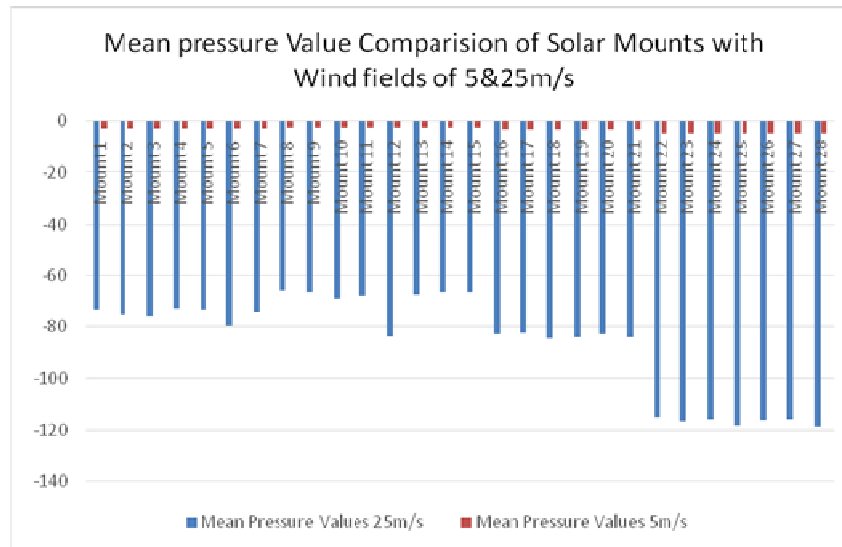


Figure 34: Comparison of Mean Pressures of the Solar Mounts with Wind Fields of 5 and 25m/s.

5. CONCLUSIONS

In the current Wind Field Simulation of Solar Farm using Computational Fluid Dynamics, the observations suggested that the Pressure Distribution is relatively high on the Higher wind velocities on the solar mounts, where the average mean pressure distribution in both cases are considered, and the highest probability of the possible dislocations or the marked trouble zones are found to be solar mount number 6, 12, 22, 23, 24, 25, 26, 27, 28. The Problematic zones in the entire farm are the last row of the structured mounts and whereas the shear layer formed on the solar mounts is probably high in the same panel numbers where from the k-epsilon Turbulence model flow, turbulence is majorly occurring in the flow past First row panels.

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